TETA TO-0016
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TEST EFFECTIVENESS TREND OBSERVATION

Adequacy of Prelaunch Testing Based on Early Flight Anomalies

CONCLUSION:

The spacecraft in-flight problem/failure rate immediately after launch is similar to the rate during Prelaunch operations. These data indicate that additional pre-launch testing or operations would reduce early flight failures. Additional operations of from 250 to 5000 hrs. are indicated by the data analyses but the effect of the space environment or preconditioning by launch vibration are yet to be determined.

DISCUSSION:

The in-flight-anomaly history was reviewed for the Mariner 71, Viking Orbiter, Voyager, and Galileo spacecraft to determine the cumulative number of anomalies beginning with operations at Kennedy Space Center and continuing to the end of the missions. This pre-launch period at KSC was selected because it provides a history of continuous full-up S/C operations prior to the mission.

The data from the four pro ects resulted in a particular pattern. Figure 1 is included to define the terms used to describe this pattern. With reference to Figure 1, the time *0* is the time at which operations started after the spacecraft arrived at KSC. The launch time is indicated by the dashed line and is labeled launch. *Pre-Launch Operations* start at the beginning of operations at KSC and continue until launch. The *Early Flight Period* begins at launch and continues until the time that the anomaly rate significantly changes. The period beginning with operations at KSC and continuing through the end of the Early Flight Period is referred to as the *First Phase*. The *Second Phase* starts at the end of the First Phase and continues either until the end of the mission or until the latest time for which data is available. The Second Phase corresponds to the *Late Flight Period*.

Plotting the pre-launch and post-launch problem/failure (P/F) data as a continuous function of time in Figures 2 and 3 reveals that the slopes of the cumulative P/Fs (which is the anomaly rate) for the time period at KSC prior to launch and the time period immediately following launch are very similar for each of the programs. The Mariner, Voyager, and Galileo spacecraft have approximately constant anomaly rates throughout the first phase. In the case of the first 1500 hours of flight for Viking, the anomaly rate varies somewhat but may be approximated by a constant rate. Using this approximation, the early flight period rates are about the same as the KSC pre-launch rates.

Figures 2 and 3 also show that the slope of the cumulative number of P/Fs subsequently decreases substantially and then continues at what appears to be a reasonably constant rate. Consequently, the post-launch anomaly data for the pro ects were divided into the early flight period, which includes anomaly rates-of-occurrence similar to those from pre-launch operations at KSC, and the late flight period that includes the remaining flight time.

The time between launch and the end of the early flight period varies from program to program. This time period is approximately 5000 hours for Mariner, 1500 hours for Viking, 250 hours for Voyager, and 700 hours for Galileo.

The cumulative anomaly plots in Figure 3, plotted for anomalies rated as having a failure effect of significant or catastrophic, are similar to those in Figure 2, which included all anomalies. The Galileo spacecraft cumulative anomalies are not included in Figure 3 because the anomalies were not failure effect risk rated as of the time these trend analysis were performed. However, at least one of the Galileo problems of very significant consequence, the antenna deployment would have escaped early detection since the mission sequence planned deployment for long after launch. The data in Figure 3 for anomalies risk rated significant or catastrophic follows the same trend as that for all anomalies.

Figures 2 and 3 show that the rate of occurrence of anomalies during the pre-launch operation phase for each pro ect is approximately constant and equal to the rate during the early flight period. Thus, the anomaly rate is approximately constant for each pro ect during the entire first phase. In addition, the anomaly rate for each of the pro ects is approximately constant during the second phase. Because the slope of the curve for the cumulative number of anomalies as a function of time is the anomaly rate and is steeper during the first phase than that during the second phase, the anomaly rate during the first phase is larger than the anomaly rate during the second phase. Thus, the rate of occurrence of anomalies as a function of time starts at a relatively large approximately constant value beginning at the time of pre-launch operation at the KSC, continues at this rate through launch and the early flight period and then decreases rapidly to a smaller approximately constant value throughout the second phase. This type of failure rate behavior resembles the reliability bathtub failure rate describing initial failures from infant mortality and subsequent random failures after all infant mortality failures have been depleted. Based on this analogy, anomalies during the first phase may be resulting from some form of infant mortality. If this analogy is correct, then the number of post-launch anomalies during the early flight period might be reduced by additional operation of the spacecraft prior to launch or by additional testing.

The data indicate additional pre-launch operations/testing would reduce early launch problems. The precise test or operations which would be most effective are being evaluated and will either be an addendum to this trend report or a new trend report. Since flight operations occur after launch vibration and in a vacuum with spaceflight temperature distributions, it is yet to be determined whether ambient operations alone are sufficient.

NONMENCLATURE FOR VARIOUS ANOMALY - HISTORY TIME PERIODS

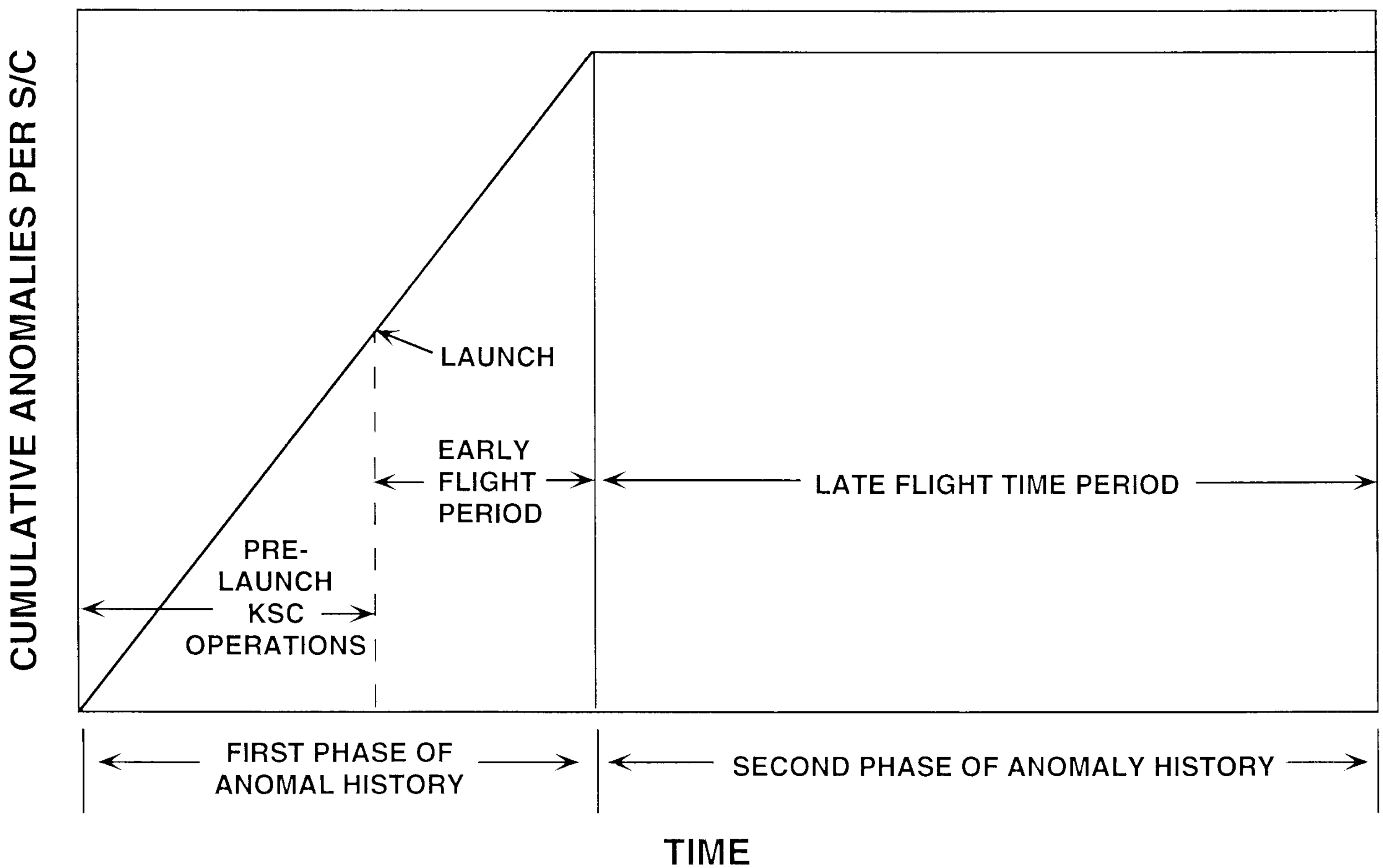


Figure 1

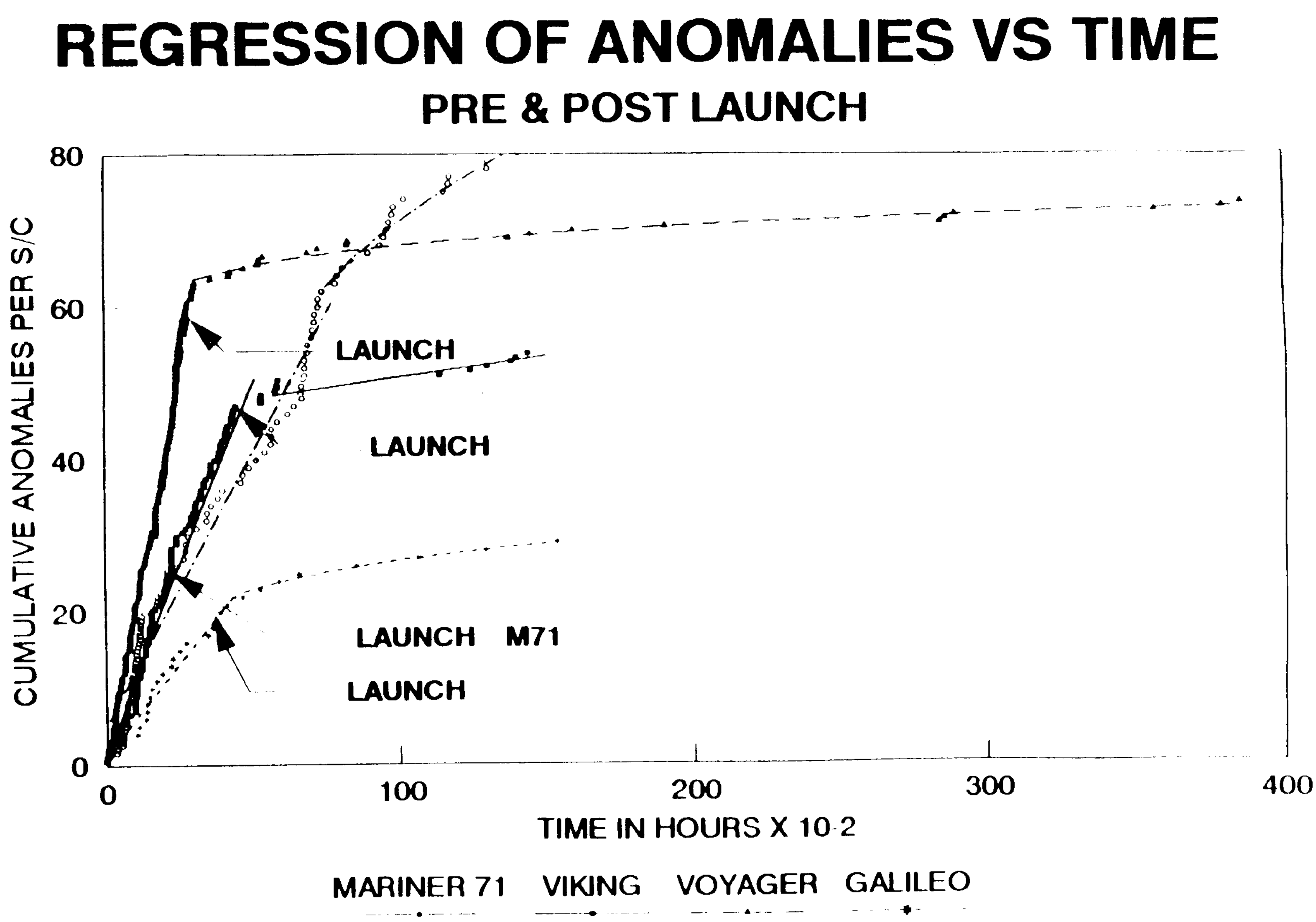
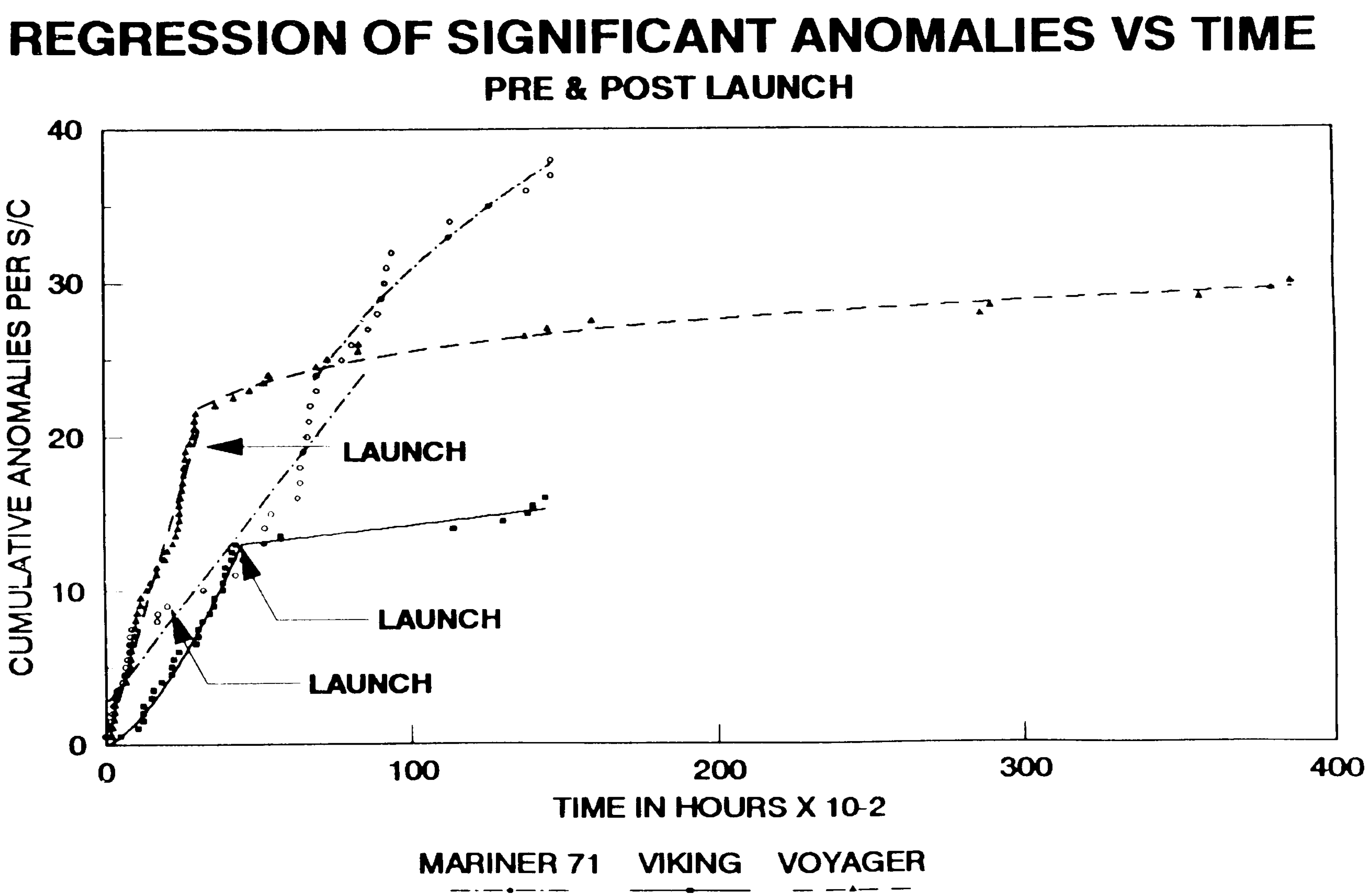

REGRESSION OF ANOMALIES VS TIME
PRE & POST LAUNCH
CUMULATIVE ANOMALIES PER S/C
80
60
40
20
0
0
100
200
300
400
TIME IN HOURS X 10-2
LAUNCH
LAUNCH
LAUNCH M71
LAUNCH
MARINER 71
VIKING
VOYAGER
GALILEO

FIGURE 2



REGRESSION OF SIGNIFICANT ANOMALIES VS TIME
PRE & POST LAUNCH
CUMULATIVE ANOMALIES PER S/C
40
30
20
10
0
0
100
200
300
400
TIME IN HOURS X 10-2
LAUNCH
LAUNCH
LAUNCH
MARINER 71
VIKING
VOYAGER

FIGURE 3